# Long Range Transport of War-Related Burn Casualties

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***Background:*** **US military burn casualties are evacuated to the US Army Institute of Surgical Research Burn Center in San Antonio, TX. Patients are transported by US Army Institute of Surgical Research Burn Flight Teams, Air Force Critical Care Air Transport Teams, or routine aeromedical evacuation. This study characterizes the military burn casualties transported by each team and reports associated outcomes.**

***Methods:*** **We performed a retrospective review of burn center registry data, identifying all US burn casualties admitted to the Army's burn center between March 2003 and February 2007. Data included total body surface area (TBSA) burn, ventilatory status, inhalational injury, associated injuries, injury severity, disposition, morbidity, and mortality.**

***Results:*** **During 4 years of military operations in Iraq and Afghanistan, 540 casualties were admitted to our burn center for treatment of injuries resulting from war-related operations. Mean burn size was 16.7% total body surface area (range, <1%–95%) with a mean Injury Severity Score of 12.2 ± 13.7. One hundred eight-one (33.5%) casualties required ventilatory support in flight; inhalation injury was confirmed in 69 (12.7%) patients. Two hundred six (38.1%) were transported by the Burn Flight Team and 174 (32.2%) were transported by Critical Care Air Transport Team, with a mean transit time of 4 days after injury. One hundred sixty (29.6%) patients were routine aeromedical evacuees. There were no in-flight deaths reported; 30 (5.6%) patients died of their wounds at our burn center.**

***Conclusions:*** **Burn casualties represent a group of patients with severe traumatic injuries. Our current system of selectively using specialty medical transport teams for the long-range transport of burn casualties is safe and effective.**

***Key Words:*** **Burns, Aeromedical evacuation, Critical care air transport.**

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United States military operations in support of the Global War on Terrorism continue throughout the world, but occur on the largest scale in Iraq and Afghanistan. Since March 2003, more than 8,000 US service members have sustained injuries from hostile action for which air transport was required.[1] Military surgeons assigned to deployed units, as well as those in Germany and at military medical facilities in the United States, continue to treat multisystem trauma which frequently includes extremity wounds, fragment injuries, and burns related to flame and explosive devices.[2] The percentage of combat wounded with thermal injury varies from war to war, ranging from 2% to 10%. Even relatively small surface area burns, such as those isolated to the hands, can represent serious war-related injury with significant long-term sequelae. Since military operations began in Iraq in March 2003, hundreds of US military personnel have sustained thermal injuries from explosions and other implements of war, severe enough to warrant specialty care at a designated burn center.[3] The United States Army Institute of Surgical Research (USAISR) Burn Center in San Antonio is the designated treatment facility for all military casualties.

Improvised explosive devices, both man-packed and vehicle-borne, have resulted in significant traumatic burn injuries.[4] Currently, combat casualties from Iraq and Afghanistan are initially evacuated from military hospitals in their respective theater of operations by US Air Force (USAF) Aeromedical Evacuation crews to the US military Regional Medical Center at Landstuhl (LRMC) in Germany. At LRMC, trauma patients are rapidly reassessed and admitted to receive further resuscitation and operative interventions as required to ensure continuity of care.[5] Patients are then flown back to one of the designated receiving hospitals in the continental US (CONUS), typically Walter Reed Army Medical Center (WRAMC) in Washington, DC, the National Naval Medical Center in Bethesda, MD, or Brooke Army Medical Center (BAMC) in San Antonio, TX.

All burn casualties are flown more than 5,300 miles (8,600 km) from Germany to the USAISR burn center, located at BAMC, for definitive care and rehabilitation; these flights are usually 12 hours to 13 hours in duration. During aeromedical transport, less severely burned patients, sched-

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uled for routine evacuation, receive in-flight care from aeromedical evacuation (AE) crewmembers. When transporting critically ill burn patients, the AE crew is augmented by either an Army Burn Flight Team (BFT) or a US Air Force Critical Care Air Transport Team (CCATT). Under these circumstances, the augmenting team assumes direct care of the patient in flight. It is the mission of both the BFT and CCATT crews to provide worldwide in-flight critical care for personnel who have sustained severe thermal and nonthermal trauma. The purpose of this study was to characterize recent combat burn casualties transported by each team, examine patient outcomes and disposition, and to analyze the process currently used to transport this group of often severely injured warriors. We expected to find that US military burn casualties were transported with the appropriate level of care based upon individual patient acuity, injury severity, and the number of patients transported.

## PATIENTS AND METHODS

During the 4-year period from March 2003 through February 2007, 1,497 patients were admitted to our burn center. Eight hundred fifty-six (57.2%) of these patients were civilian emergency patients from San Antonio and the surrounding region and 656 (43.2%) were military personnel including active duty, family members, and retirees. Thermal injuries occur in a variety of working environments and result from various mechanisms of injury, including direct combat action, explosions, shipboard crashes, and use of pyrotechnics.

Using a protocol approved by our Institutional Review Board, we performed a retrospective review of data collected from the burn center registry of all US military burn casualties injured in Iraq or Afghanistan who were transported from LRMC to our burn center between March 2003 and February 2007 by a BFT, CCATT, or AE crew alone. Data included total body surface area (TBSA) burn, ventilatory status, presence of associated injuries including inhalational injury, injury severity, disposition, morbidity, and mortality. Patients who were transported because of inhalation injury alone, without cutaneous burns, or for skin and soft tissue conditions such as necrotizing fasciitis, toxic epidermal necrolysis, or heparin-induced thrombosis were excluded from analysis.

## RESULTS

### Patients and Characteristics

Five hundred forty US combat casualties, with an average age of 25.9 years (range, 19–52 years), were flown from Germany to San Antonio for treatment at our burn center during the 4-year study period; 522 (96.7%) were men and 18 (3.3%) were women. The majority (73.2%) of the casualties were Army personnel (Table 1). War-related burn casualties represented 36% of the total 1,497 burn center admissions during the study period. Mean burn size was 16.7% TBSA (range, 0.1%–95%); 149 (27.6%) had burn wounds greater than 20% TBSA. Thermal injury was directly related to an explosion in 342 (63.3%) cases, most often an improvised explosive device. One hundred eight-one (33%) casualties required ventilatory support during transport; inhalation injury was confirmed in 69 (12.8%) burn patients.

**Table 1** Casualties by Branch of Service

| US War-related Burn Casualties Mar 2003–Feb 2007 | Number (%) |
|---|---|
| Army | 395 (73.2) |
| Navy | 10 (1.8) |
| Air Force | 7 (1.3) |
| Marines | 128 (23.7) |
| Total | 540 |

### Associated Injuries

The average Injury Severity Score (ISS) was 12.2 ± 13.7 and an ISS of 16 or greater was reported for 169 (31.3%) patients, generally reflecting the presence of severe associated injuries. The lack of statistically significant different ISS between the BFT and CCATT groups was expected, as the burn injury itself was often the less severe of multiple injuries transported by CCATT. Two hundred seventy-five (50.9%) patients had multiple traumatic injuries with fractures of the lower extremity being most common. Tibial fractures were found in 29 (5.4%) patients. Femur fractures were noted in 20 (3.7%) patients and 12 (2.2%) patients were noted to have ankle fractures. Upper extremity fractures included the radius or ulna in 18 (3.3%) patients followed by fractures of the humerus in 15 (2.7%) patients. One hundred nine (20.1%) patients required escharotomies of one or more extremities and 93 (17.2%) patients required fasciotomies because of the severity of their wounds or because of compartment syndrome. Other serious injuries included closed head injuries, traumatic brain injury, and injuries to the lungs or intraabdominal organs.

### Transport Information

The BFT transported 206 (38.1%) patients on 57 flight missions and 174 (32.2%) patients were transported during 85 CCATT missions. The mean transit time, defined as the period from the day of injury until arrival at the burn center, was just under 4 days for both groups of intubated patients (Table 2). When all patients were considered, the BFT patients arrived at the burn center slightly sooner than the CCATT patients. The remaining 160 (29.6%) patients were classified as routine aeromedical evacuees and arrived at the burn center approximately 7 days after injury. The patient manifest for each mission ranged from 1 to 13 burn patients.

### Outcomes

Five hundred ten (94.4%) of the transported patients survived their injuries. The length of hospitalization at our burn center averaged 26 days, ranging from 1 day to 496 days (Table 3).

**Table 2** Comparison of Burn Casualties Transported*

| Variable | Burn Flight Team | CCATT | p |
|---|---|---|---|
| No. patients | 206 (38.2%) | 174 (32.2%) | 0.0354 |
| Flight missions | 57 | 85 | NA |
| Average patients per flight mission | 3.7 ± 2.8; range, 1–13 | 2.0 ± 1.2; range, 1–8 | NS |
| Mean %TBSA | 25.9 ± 25.2 | 16.0 ± 15.0 | 0.0012 |
| >20% TBSA | 91 (44.2%) | 56 (32.2%) | 0.0079 |
| Mean ISS | 16.7 ± 16.5 | 14.2 ± 12.4 | 0.0464 |
| Associated injuries | 122 (59.2%) | 104 (60.5%) | NS |
| Ventilated | 102 (49.5%) | 79 (44.8%) | NS |
| Inhalation injury | 45 (21.8%) | 24 (13.8%) | 0.0464 |
| Transit time | 3.68 ± 1.89 | 4.38 ± 2.42 | 0.0011 |
| Transit time for ventilated patients | 3.42 ± 1.37 | 3.65 ± 2.11 | NS |
| Burn center length of stay | 38.0 ± 57.8 | 28.0 ± 56.6 | 0.0175 |

* Trauma patients without burns were not included in analysis.
NA indicates not assayed; NS, not significant.

**Table 3** Burn Casualty Characteristics

| Variable | BFT | CCATT | Routine AE | Overall |
|---|---|---|---|---|
| Patients | 206 (38.2%) | 174 (32.2%) | 160 (29.6%) | 540 |
| Age (yr) | 26.5 ± 6.4 | 25.9 ± 6.4 | 25.2 ± 5.9 | 25.9 ± 6.26 |
| Mean %TBSA | 25.9 ± 25.2 | 16.0 ± 15.0 | 5.6 ± 4.0 | 16.7 ± 19.7 |
| ISS | 16.9 ± 16.5 | 14.2 ± 12.4 | 4.2 ± 4.9 | 12.2 ± 13.7 |
| Ventilated | 102 (49.5%) | 79 (45.9%) | 0 | 181 (33.5%) |
| Inhalation injury | 45 (21.8%) | 25 (14.4%) | 0 | 70 (12.9%) |
| Transit time (d) | 3.68 ± 1.89 | 4.38 ± 2.42 | 6.7 ± 4.2 | 4.8 ± 3.2 |
| Mean length of stay (d) | 38.0 ± 57.8 | 28.0 ± 56.6 | 8.7 ± 9.8 | 26.1 ± 49.7 |
| Mortality | 27 (13.1%) | 3 (1.7%) | 0 | 30 (5.6%) |

Two hundred ninety-four (54.4%) patients returned to duty after their hospitalization. One hundred four (19.3%) patients had one or more traumatic injuries that prevented them from continuing their military service as determined by a Medical Evaluation Board process. Currently, 112 (20.7%) burn patients are classified as Warriors in Transition as they continue their rehabilitation until the full extent of their physical disability is determined. (Table 4) There were no in-flight deaths reported. However, unscheduled diversion was requested for four patients enroute between Germany to San Antonio; two of these patients died at the alternate destination and two were later admitted to burn center. Among the 30 (5.6%) patients who died of their wounds at the burn center, the median burn size was 67% TBSA, the mean %TBSA was 63.1 ± 22.3, and the mean ISS was 39.9 ± 16.1, ranging from 22 to 75 (Table 5).

**Table 4** Disposition of Patients Compared With Severity of Injury

| Patient Disposition | Number (%) | Mean % TBSA | Mean ISS |
|---|---|---|---|
| Returned to duty (RTD) | 294 (54.4) | 7.1 ± 6.6 | 5.3 ± 6.4 |
| Medically boarded (MEB) | 104 (19.3) | 20.2 ± 16.3 | 16.0 ± 11.6 |
| Warrior in transition (WIT)* | 112 (20.7) | 26.2 ± 21.7 | 19.3 ± 14.6 |
| Died of wounds (DOW) | 30 (5.6) | 63.1 ± 22.3 | 39.9 ± 16.1 |
| Total | 540 | 16.7 ± 19.7 | 12.2 ± 13.7 |

Warriors in transition may ultimately undergo Medical Evaluation Board.

## DISCUSSION

Survival of the critically injured burn trauma patient depends on many factors including timely access to facilities able to provide expert care.[6–8] The provision of military burn care mirrors the civilian standards set by the America Burn Association and the Advanced Burn Life Support Program. Casualties are initially treated by military medics or corpsmen closest to the point of injury. Initial treatment is focused on the priorities of airway protection, hemorrhage control, and initiation of volume resuscitation. The wounded are then rapidly evacuated to the next higher level of care where the patient can be further assessed and stabilized. The evacuation plan for the burn casualty is to stabilize and prepare the patient for transport back to the USAISR Burn Center as safely and expeditiously as possible to facilitate early excision and grafting, minimize ventilatory days, and institute rehabilitation therapy.

Burn patients injured in CONUS generally experience relatively short transport times and arrive at a definitive care facility within several hours after injury. Certain regions of the country experience somewhat longer evacuation times as noted by Klein et al.[9] US military medical personnel are capable of providing critical care during both tactical intrath-

**Table 5** Mortality Data

| Casualty | Branch | TBSA Burn (%) | ISS | Inhalation Injury | Transport Team |
|---|---|---|---|---|---|
| 1 | Army | 93.3 | 75 | No | BFT |
| 2 | Army | 92.0 | 29 | No | BFT |
| 3 | USMC | 92.0 | 75 | Yes | BFT |
| 4 | Army | 92.0 | 75 | Yes | BFT |
| 5 | Army | 83.5 | 25 | No | BFT |
| 6 | Army | 80.0 | 34 | No | BFT |
| 7 | USMC | 78.0 | 34 | No | BFT |
| 8 | USMC | 77.5 | 34 | No | BFT |
| 9 | USMC | 76.0 | 34 | No | BFT |
| 10 | Army | 75.0 | 54 | Yes | BFT |
| 11 | Army | 75.0 | 50 | Yes | BFT |
| 12 | Army | 71.5 | 34 | Yes | BFT |
| 13 | Army | 71.0 | 50 | Yes | BFT |
| 14 | Army | 70.0 | 25 | No | BFT |
| 15 | USMC | 69.0 | 50 | Yes | BFT |
| 16 | Army | 65.0 | 34 | Yes | BFT |
| 17 | USMC | 65.0 | 43 | Yes | BFT |
| 18 | Army | 60.0 | 59 | Yes | BFT |
| 19 | Army | 59.5 | 34 | Yes | BFT |
| 20 | USMC | 56.0 | 26 | Yes | BFT |
| 21 | Army | 55.5 | 51 | Yes | BFT |
| 22 | Army | 55.0 | 25 | No | BFT |
| 23 | Army | 54.0 | 25 | No | BFT |
| 24 | Army | 51.0 | 25 | No | CCATT |
| 25 | Army | 51.0 | 26 | Yes | BFT |
| 26 | USMC | 48.0 | 25 | No | BFT |
| 27 | Army | 31.5 | 25 | Yes | BFT |
| 28 | Army | 30.0 | 50 | No | BFT |
| 29 | Army | 8.0 | 50 | Yes | CCATT |
| 30 | Army | 6.5 | 22 | No | CCATT |
| Mean ± SD | | 63.1% ± 22.3 | 39.9 ± 16.1 | Yes = 16 (53.3%) | |

USMC, United States Marine Corp.

eater evacuation and generally longer strategic intertheater transport of casualties. With this capability, patients are typically transferred from anywhere in the world, including Iraq or Afghanistan, to CONUS within 4 days of being wounded. In comparison, Treat and coworkers reported that burn casualties injured in Vietnam between 1968 and 1972 generally arrived at the Army's burn center weeks after injury.[10,11]

## Initial Management and Consultation

Initial management of the burn casualty in the combat zone requires a strategy of rapid assessment, airway protection, and appropriate resuscitation in addition to a thorough examination for associated injuries common to the battlefield casualty. Patients with severe facial burns, those demonstrating signs or symptoms suggestive of inhalation injury, and those with large burns for which a significant resuscitation and associated edema are anticipated, are often preemptively intubated soon after injury to ensure airway protection and mechanical ventilatory support. Appropriate volume replacement in the burn patient can be very challenging, requiring that the practitioner provide adequate intravascular replacement, whereas simultaneously striving to avoid the potentially devastating complications associated with high-volume crystalloid resuscitation as noted by Chung et al.[12]

Primary and secondary trauma surveys of the combat injured often reveal multiple injuries, including multiple open soft tissue wounds, in addition to burn wounds. Many casualties are injured while traveling in a moving vehicle and need evaluation for blunt injury, as well as penetrating injury from an explosion. After initial assessment in the emergency medical treatment area, patients are often transported directly to the operating room at the initial military hospital for debridement of all wounds and treatment of associated injuries, including placement of external fixation devices for stabilization of fractures. Circumferential burn wounds of the extremities are prone to the potentially devastating effects of vascular compromise as the subcutaneous tissues are constrained by the restrictive eschar. Early performance of fasciotomies of the burned extremities is indicated when compartment syndrome is suspected. The burn patient is also extremely susceptible to hypothermia because of his or her inability to maintain thermoregulation, which can further complicate the condition of the trauma patient who may already demonstrate acidosis or coagulopathy or both.

To assist in the management of burn patients, USAISR Burn Center physicians, physician assistants, and nurses are continuously available by phone or e-mail for consultation. Since early 2005, the USAISR has deployed a burn surgeon

to Iraq to serve as both trauma surgeon and theater consultant for burns. Although the theater consultant is not able to examine every burn patient, he or she is able to provide rapid consultation and facilitate the evacuation process, especially when internet access and digital imagery is available.

An electronic consultation system established by the US Army Medical Command speeds access to care as key medical information is sent from theater hospitals back to the Burn Center at Fort Sam Houston. The value of early telephone communication and email between providers along the evacuation route cannot be overemphasized. A relatively recent and major enhancement in the transmission of critical patient information is provided by the Joint Patient Tracking Application. The Joint Patient Tracking Application is a Department of Defense web-based software utility which enhances the provision of care by allowing providers to review care provided along the evacuation route. Weekly videoteleconferences between theater and CONUS facilities also enhance care by providing rapid performance improvement.

Evacuation of the combat casualties is managed by the Theater Patient Movement Requirements Center. The Patient Movement Request initiated for each burn casualty identifies BAMC as the definitive receiving medical facility. Current US evacuation policies support urgent or priority transport for burn casualties based upon the severity of injuries. US Transportation Command policy regarding the transport of burn casualties provides guidelines similar to American Burn Association burn center admission criteria based on the severity of burn injury, the presence and severity of inhalation injury and other associated injuries[13] (Table 6). Timely transmittal of casualty information between providers allows for early consultation and rapid mobilization of the appropriate evacuation teams.

## AE Teams

AE is a major operational competency of the Air Force Medical Service. AE crews aboard Air Force aircraft have been transporting America's wounded since World War II.[14] Today's standard AE crew is comprised of two Flight Nurses and three AE Technicians. Patients are transported on "aircraft of opportunity", usually cargo aircraft that are empty after unloading supplies in the war zone. Currently, the C-17 Globemaster III is the principle long-range transport aircraft used for AE. With a cruising speed of 450 knots, it is designed to carry 36 litter and 54 ambulatory patients and attendants, and routinely makes the journey between Ramstein Air Base in Germany to San Antonio in approximately 12 hours. Each C17 is equipped at all times with stanchions and equipment for nine litter patients. AE crews are specially trained to configure any USAF cargo aircraft to meet AE mission requirements. Both CCATT and BFT crews augment the AE personnel assigned to every AE mission. The medical crew director is part of the organic AE crew assigned to an evacuation mission.

**Table 6** **USTRANSCOM Guidelines for Specialty Burn Flight Team Utilization**

| Patients With the Following Criteria Should be Considered for Transport by Burn Flight Team |
|---|
| Burns involving more than 20% of the total body surface area |
| Inhalation injury requiring intubation and mechanical ventilation |
| Burn patients with severe mechanical trauma |
| Burn or inhalation injury patients with $P_{AO_2}$ to $FIO_2$ ratio of less than 200 |
| High voltage electrical burns |
| Any other burn patient whose severity of illness or injury merits burn specialty team transport as determined by the attending, validating, or receiving surgeon |

## Transport Options

The decision whether to transport a particular patient attended only by the AE crew, or to augment the AE mission with either a CCATT or a BFT is based upon many factors, including the number and severity of burn patients, their overall clinical status, and the presence of inhalation injury. In the case of the stable patient ready for transport at the time of a scheduled mission that already includes a CCATT, the decision may favor using a CCATT rather than incurring the delay inherent in activating a BFT that must travel from their home station in San Antonio; CCATT personnel are based near LRMC, at Ramstein Air Base along with the AE crews that routinely perform AE missions back to CONUS.

The patient's pulmonary status and response to conventional ventilatory support is often a key factor in the decision to request a BFT. One hundred eighty-one (33%) of the burn patients required intubation and ventilatory support and inhalation injury was confirmed in 69 (12.8%) of the patients studied. On occasions when a burn casualty is stabilized for flight, and is adequately oxygenated using conventional ventilatory support, it may be more prudent to manifest the patient with an available CCATT crew rather than delaying transport to await the arrival of a BFT. Conversely, BFT personnel are experienced and equipped to manage multiple burn patients with inhalation or pulmonary injury, which requires ventilatory support beyond the capabilities of traditional transport ventilators. The BFT carries portable fiberoptic bronchoscopes as part of its standard equipment package in the event bronchoscopy is required for diagnosis or treatment in flight. Frequently multiple patients sustain thermal injuries in the same explosion and the BFT is ideally suited to transport multiple burn casualties, as well as trauma patients without thermal injuries, designated for evacuation back to BAMC.

## Air Force CCATT

Casualty transport from Iraq or Afghanistan to Germany is performed by Air Force AE crews, generally augmented by a CCATT. The Air Force CCATT program was launched in 1994 in support of evolving military medical doctrine to meet the challenge of transporting seriously injured military patients requiring critical care expertise.[14] Since 2003, CCATT

**Fig. 1.** *CCATT crew in flight.*

crews have transported thousands of US military patients from war zones to Germany. The 3-person CCATT crew includes a critical care physician, typically one specialized in pulmonary medicine and critical care, emergency medicine, anesthesiology, or surgery, a critical care registered nurse, and a cardiopulmonary technician (Fig. 1). Key to the success of these teams is their daily involvement with critical care in their hospital practice. CCATTs are equipped to provide care for three to six patients depending on the level of patient acuity.

The experience of a given CCATT crew caring for burn patients is variable based on their clinical specialty and previous flight experience. CCATT personnel receive training in management of burn patients during both the initial and advanced CCATT courses. USAISR BFT members serve as adjunct faculty at the initial CCATT course. The value of this frequent interaction between the teams has been demonstrated on multiple occasions where CCATT and BFT crews have flown together, caring for both burn and trauma patients destined for CONUS.

## Army BFT

The mission of the USAISR is to enhance and improve care provided to the battlefield casualty, through both research and advanced clinical care. The USAISR Burn Center is designated as the definitive care facility for all US Armed Forces personnel who sustain severe burns. Clinicians and researchers assigned to the USAISR are actively involved in all aspects of burn and trauma care. Surgeons deployed from the USAISR participate in the treatment of warriors from their early assessment and treatment at deployed facilities such as those in Iraq through the process of evacuation back to the military's only combined American College of Surgeons verified Level I trauma center and American Burn Association verified burn center.

Since 1951, the United States military has used the Army's BFT to transport severely burned personnel, including those injured in combat, during training exercises, or related to injuries from other causes, to its burn center for definitive care.[15,16] The rationale for a specialized BFT mirrors that used by burn centers themselves—patients benefit from specialized care afforded to them by personnel who work daily with critically ill burn patients.

In addition to caring for the combat casualty, the USAISR Burn Center supports the Army's Special Medical Augmentation Response Team (SMART) system. The SMART-Burn consists of burn center personnel organized to perform consultation, assessment, treatment, and transport missions as assigned. The SMART-Burn mission can be tailored for homeland defense contingencies or to respond to natural disasters where burn specialty team support is required.

Each of the BFTs has five personnel assigned to the USAISR Burn Center, who work daily in one of the center's intensive care units (ICUs). Team size and composition can be augmented based on the number and complexity of patients to be transported. Each BFT carries with them equipment and supplies necessary to provide complete ICU level care within the austere transport environment. The leader for each BFT is a general surgeon experienced in the areas of burn, trauma, and surgical critical care, including the management of patients with severe lung disease commonly seen with inhalation injury. Each of the BFT surgeons is credentialed to operate and perform surgical interventions at LRMC as needed before transporting the patients back to the burn center.

The lead flight nurse for each BFT is a critical care Registered Nurse with significant burn and critical care experience. A Licensed Vocational Nurse serves as the second flight nurse on the team, and has completed the Army's critical care nursing program as designated by a specialized career identifier (68WM6). Respiratory care is provided in-flight by a Certified Respiratory Therapist (68V) with extensive experience in using a variety of ventilators and in treating patients with severe lung disease and inhalational injury (Fig. 2). The operations noncommissioned officer for the team is also a medical technician who serves as both the operations officer for each mission, and provides assistance to the flight team as needed.

One of the most unique aspects of the BFT involves continuity of care. The BFT surgeon who assesses the patient in Germany routinely becomes the attending physician for the

**Fig. 2.** *Burn Flight Team members attending to patient.*

patient and is actively involved in the care of the patient throughout his or her stay at the burn center, in the ICU, in the operating room, and throughout the process of rehabilitation and reconstruction.

The shorter transit time for the BFT may be explained by one or more factors: CCATT crews often fly from Germany to CONUS on a set schedule, with an intervening stop in CONUS to allow patients destined for WRAMC or National Naval Medical Center to disembark. The BFT is typically scheduled for a priority flight directly from Ramstein Airbase to San Antonio, which can save 6 or more hours in transit. The BFT routinely adds any and all burn patients, as well as any other patients at LRMC destined for BAMC to their flight mission, thereby maximizing utilization of limited airframes and expediting transport to the burn center and BAMC. This process often frees a CCATT to fly another mission, thereby maximizing the capabilities of both teams, which exist in limited numbers.

## Critical Care in Flight

The priorities of care in flight are the same as those used in the modern intensive care trauma unit, regardless of the team providing the care. The manner in which care is provided, however, may be markedly more challenging in flight than on the ground. Long-range air transport is affected by the isolated nature and austere environment of the aircraft, which allows for finite staffing and limited supplies and equipment. Airway protection and maintenance is a continuous focus for all team members during flight. Adequacy of breathing and ventilatory support is continuously monitored in flight using pulse oximetry and interval arterial blood gas measurements. Arterial blood gas measurements, as well as basic laboratory values, such as hematocrit and basic chemistry are obtained in flight using the i-STAT blood analyzer (Abbott Medical Diagnostics Products, East Windsor, NJ) allowing the team to adjust ventilatory support and replace electrolytes as required.

Continuous cardiac monitoring is accomplished using the PROPAQ Encore 206 EL (Welch Allyn, Skaneateles Falls, NY) secured to the SMEED Special Medical Emergency Evacuation Device (Impact Instrumentation, West Caldwell, NJ) which is then attached to the standard North American Treaty Organization (NATO) litter. The SMEED was designed at the USAISR, by a former member of the BFT, to provide a solid, yet lightweight platform upon which to mount multiple medical devices. Crewmembers must use visual cues on the monitors as the alarms are inaudible against the drone of aircraft noise.

Hemodynamic support using pressor agents is required for a subset of patients and the use of these medications is generally managed with the use of continuous arterial blood pressure monitoring. Venous and arterial access lines sewn in place for added security must be intermittently inspected during flight for patency and security. Both BFT and CCATT use the IVAC Medsystem III (Cardinal Health, Dublin, OH) for infusion of maintenance and resuscitative fluids as well as pressor agents. Pain management and sedation are closely monitored and controlled using intravenous medications administered through the IVAC system. Exposure to the environment of the aircraft and thermoregulation remains a challenge in the care of most burn patients. Heat loss from multiple open wounds, including temporary abdominal closures must be taken into consideration. Refinements in airborne aircraft environments have provided greater cabin temperature control, which facilitates improved patient comfort and thermoregulation. Fluid management, monitoring of input and output volumes, and controlling fluid replacement is a continuous process during the flight. Urinary output is closely monitored to avoid either inadequate or excessive fluid replacement required for both ongoing resuscitation and insensible losses.

To enhance their knowledge of the unique requirements and rigors of providing care at high altitudes in the austere aeromedical environment, as well as strengthen the effective working relationship with Air Force Medical Service personnel, BFT team personnel complete the CCATT initial course along with new CCATT members at the US Air Force School of Aerospace Medicine. Before deployment, CCATT members also attend two additional weeks of training at the Center for Sustainment of Trauma and Readiness Skills located at the Cincinnati University Hospital Trauma Center, Cincinnati, OH. This training hones the abilities to provide care in the aeromedical environment.

Military aircraft transporting patients destined for the Burn Center at Fort Sam Houston generally land at either San Antonio International Airport or at Kelly Air Force Base. Each of these airfields is able to accommodate the C17 transport aircraft. Medical transportation between the arrival airfields and BAMC varies depending on the number and priority of the patients. Advanced Life Support ambulances, staffed with Paramedics are routinely used for transport of burn patients as they provide temperature controlled, radio equipped emergency vehicles able to negotiate the traffic even during the most congested periods. Military ambulance buses (Ambus), which can transport multiple patients while maintaining integrity of the transport team and equipment, are also used.

## Ventilatory Support

The patient's severity of injury, pulmonary status, and response to ventilatory support dictates the choice of ventilator and ventilator mode during transport. Patients with inhalation injury can require significant ventilatory support beyond the capabilities of conventional devices and highlights one of the most common reasons for using the BFT. In addition to the Uni-Vent Eagle Model 754 (Impact Instrumentation, Inc, West Caldwell, NJ) and LTV 1000 (Pulmonetics, VIASYS Healthcare, Inc, Minneapolis, MN) transport ventilators used by CCATT crews, the BFT uses both the VDR-4 and the TXP (Percussionaire Corp, Sand Point, ID).[17]

Extensive use of the Percussionaire Volumetric Diffusive Respirator (VDR) by our burn center to treat patients with inhalation injury and other severe pulmonary dysfunction led to the inclusion of the VDR in the team's standard equipment list. The TXP pressure control ventilator is also used by the BFT because of its simplicity, compact size, and effectiveness. The TXP is driven by compressed oxygen and has no electrical requirements. The basic VDR-4 also requires no electrical power, however, an ample supply of dry, compressed air is required during long-duration flights. The Aridyne 3500 Medical Air Compressor (Timeter Instrument Corporation Allied Health Care Products, St Louis, MO) is certified by the USAF for use in flight and provides a ready source of compressed air for the VDR-4.

### Minimizing Complications In-Flight

Patients are carefully assessed by CCATT or BFT personnel before flight to ensure they are stabilized for the 12-hour to 13-hour flight. Assessment includes an in-depth review of the medical record, physical examination, and review of all recent laboratory data and radiographs. Every precaution is taken to avoid emergency procedures in-flight. All patients, whether scheduled for transport by CCATT or BFT, are assessed by a validating flight surgeon to help ensure that the patient can be transported safely. Although the validating flight surgeon is primarily focused on patient safety related to the physiology of flight, this medical officer provides another objective assessment of the patient's status before flight.

Despite these efforts, four patients required unscheduled in-flight diversion between Germany and San Antonio. Two of the patients died at the alternate facility, and two were later transported to the Burn Center and subsequently discharged. Both patients who died before arriving at our burn center demonstrated severe hypotension consistent with sepsis, but were unresponsive to multiple pressor agents and volume; neither demonstrated significant anemia. Postmortem examination of these patients revealed no findings to fully explain their decompensation such as evidence of pulmonary embolism, bleeding, myocardial infarction, or intestinal ischemia associated with abdominal compartment syndrome. One of the patients who required in-flight diversion, but survived, demonstrated bloody output from his abdominal drain and a marked decrease in hematocrit suggestive of bleeding from his operative site. He was deplaned enroute to the burn center, and underwent abdominal exploration, which revealed no evidence of bleeding. He tolerated subsequent transport well and was flown to the burn center for treatment and eventual discharge. The fourth patient experienced a brief unscheduled stop at WRAMC and was later transported to the burn center without further sequelae.

Concerns regarding long-range flight and prolonged bed rest and immobility heightened concern for deep vein thrombosis among evacuated patients. Chung and colleagues at the USAISR recently reported that subjecting military burn patients to prolonged global evacuation did not increase venous thromboembolic complications when compared with the local civilian emergency patients. Unless contraindicated, chemical prophylaxis with low molecular weight heparin is often administered before, and in flight, in an effort to reduce the risk of deep vein thrombosis and pulmonary embolism.

Volume resuscitation of the burn patient during the first 72 hours after injury remains a significant challenge for providers at all levels. Both over- and under-resuscitation of the burn patient can lead to serious complications. The challenge is even greater as patients are transferred between at least three facilities, separated by a distance of several hundred to thousands of miles. Efforts to improve the process of fluid resuscitation throughout the evacuation process include web-based publication of consensus guidelines and development of a burn resuscitation flowsheet to be used during the first 24 hours to 72 hours after injury.

Our regression analysis of the data examining age, %TBSA, ISS, intubation, and inhalation injury as possible predictors of mortality. Not surprisingly, only %TBSA and the ISS proved to be predictive of mortality (Table 6).

## CONCLUSIONS

Burn casualties represent a group of seriously injured warriors. Rapid treatment and critical care transport remain vital to the survival of the burn casualty injured thousands of miles away from definitive care. Current policies and procedures provide early consultation, both remotely and in theater; early communication between deployed providers caring for the burn casualty and the burn center staff is important. Joint training such as the CCATT course and Joint Combat Predeployment courses provide essential education for those who will provide initial care and in-flight management of burn and trauma patients.

Our review of the data collected from 4 years of combat operations confirmed our hypothesis that burn casualties are well served by the current system used by the US Armed Forces to evacuate patients from foreign soil back to the military's burn center. Our data supports the current practice and policy of augmenting AE missions with CCATT or BFT crews depending upon the number of patients, the severity of their injuries, and the clinical judgment of the physicians caring for the patient. The joint system currently employed provides state of the art care for severely burned casualties with unprecedented rapidity when compared with that used just several decades past.

Although the relatively low mortality rate and high return to duty rate among the burn casualties is encouraging, many challenges remain. Research to develop closed-loop resuscitation algorithms coupled with advanced monitors and digital urimeters holds much promise. The development of lightweight, multifunctional devices that combine ventilator support, hemodynamic monitoring, and multiple device controllers will also benefit aircrews managing several critically injured patients in-flight.

Based on patient outcomes, the criteria used to determine when and how to augment AE missions transporting burn casualties from the war in Iraq and Afghanistan appears to be appropriate and efficient. Current guidelines maximize the capabilities of highly specialized, yet very limited resources available within the Army and Air Force. The current system encourages teamwork while striving to match severely injured patients with the appropriate team, at the right time, and at the right place.

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## DISCUSSION

**Dr. Stephen L. Barnes** (Division of Trauma and Critical Care, University of Cincinnati, Cincinnati, OH): Dr Renz and his colleagues from the USAISR present an excellent descriptive analysis with outcomes of the final stage of the global aeromedical evacuation of burn related casualties in support of OEF/OIF. Significant burns, especially those with associated combat related trauma and inhalational injury are some of the most challenging patient movements in our current en route casualty care system. The Burn Flight Team has been moving patients for nearly 60 years. In 1993, the USAF embarked on formalization of critical care in the air with the development of Critical Care Air Transport Teams, modeled in part, after the Burn Flight Team. Although more general in construct and for the most part staffed by nonsurgeons, the three person CCAT teams have moved more than 3,400 severely injured and disease stricken patients in support of OEF/OIF. They do not, however, have the same level of experience or all of the equipment provided by the Burn Flight Team to comfortably manage severely burned casualties. I have a few questions for the authors. Is the Burn Flight Team effective because of the team construct of individuals involved in the day-to-day care of the burn patient? How much does the difference in equipment packages and personnel between CCATT and BFT come into play in the clear decision, based on your data, to have the Burn Flight Team move the more severely burned and a greater proportion of patients with inhalational injuries? Most, if not all patients are transported out of the AOR to Germany by CCAT teams. If equipment plays a significant role in effective movement, should we be making changes to the USAF CCATT equipment package to better manage these casualties? Do you have data on patients who died of wounds at LRMC after CCATT aeromedical evacuation? If so, what role do you think team inexperience in burn management or equipment played in these outcomes?

The USTRANSCOM guidelines for Burn Flight Team utilization are very general. Can you be more specific as to the most effective deployment of the Burn Flight Team and do you think that evaluation of your data set will lead to more specific guidelines for Burn Flight Team deployment?

To my knowledge this is the first description with outcomes of Burn Flight Team utilization with comparison between CCATT and BFT movements and the authors should be applauded for their efforts. They have demonstrated that our aeromedical en route care system, though complex in construct, is both safe and effective for the movement of our

thermally wounded warriors. Thank you for the opportunity to review this article.

**Dr. Evan M. Renz** (US Army Institute of Surgical Research, Fort Sam Houston, TX): The authors are grateful to Dr Barnes for his insightful comments and offer the following responses to the questions raised.

One of the main advantages possessed by the Burn Flight Team in caring for severely burned trauma patients stems from the fact that the entire team is comprised of personnel who are immersed in the care of burn patients, many of whom are critically ill. The authors would submit that being able to translate experience gained through working daily in the Burn Intensive Care Unit, and studying the unique pathophysiology of burns through ongoing research and practice, offers a decided benefit to the patient.

In response to the question of whether equipment or personnel provide a unique advantage to the team, the answer is both. Our institution's experience using the VDR over the past few decades to support patients with severe inhalation injury provides an option that we think is uniquely beneficial. The VDR does require that both the physician and the respiratory technician possess significant experience in its use to maximize its effectiveness. We are currently implementing a randomized control trial comparing the VDR4 with conventional ventilatory support to help us determine the validity of our practice. It is our hope that our group will be able to provide data to help answer the question of ideal equipment for supporting burn patients in the near future.

With respect to the question of need and feasibility for additional guidelines detailing the employment of the BFT, we would offer that the answer lies in education and dissemination of information. Our efforts to maximize training in burn care through the Joint Forces Deployment courses, CCATT, and other educational programs continue to enable providers to better assess burn patients before transport and request consultation as needed. Discussion forums such those provided through the Joint Theater Trauma System videoconferences also supplement the guidelines. We have striven to help develop practical guidelines which assist the clinician in providing safe and timely evacuation for the burn patient, while taking into account the likelihood of other associated injuries.